SatNetBuilder
Building the Internet in Space

The Role of Simulation in Design

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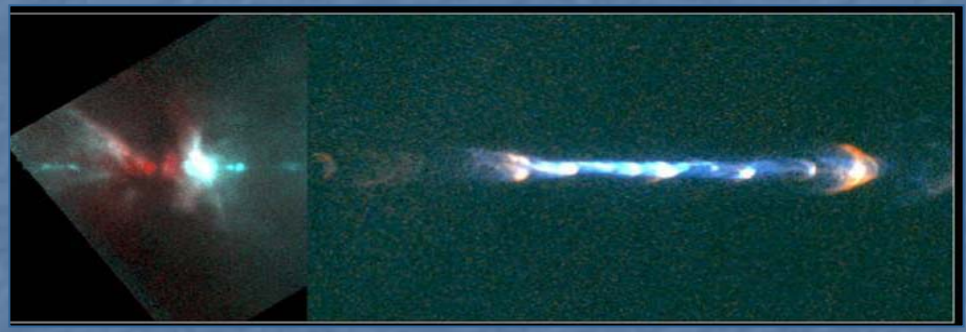
Table of Contents

What Are Simulations?

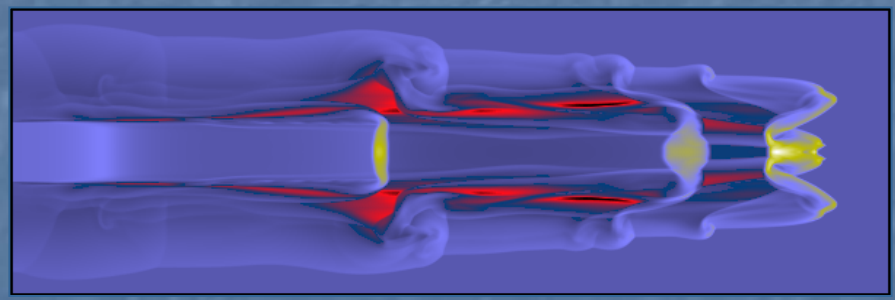
- Many visions of Simulation in popular culture
  - “The Matrix” trilogy of movies.
  - “The 13th Floor”
  - “The Sims” video game
- People understand Simulations to mean a “virtual” or “digital” recreation of reality.

What Are Simulations?

- Science uses Simulation in more narrow and focused sense.
- Scientific Simulation = digitally solve mathematical models for phenomena under study



HST image of jet from young star



Simulation of jet from young star

How Science Works: Astronomy Observation vs Theory

- Observation
  - Use telescopes
  - Visual/Infrared/X-rays..
  - Gather Data
  - Refine Data
  - First Cut at Interpretation
- Theory
  - Interpret data
  - Global Interpretation!
  - Objects and Classes of Objects
  - Mathematics is means of description.

Why Simulate?

Simulation is a third way.

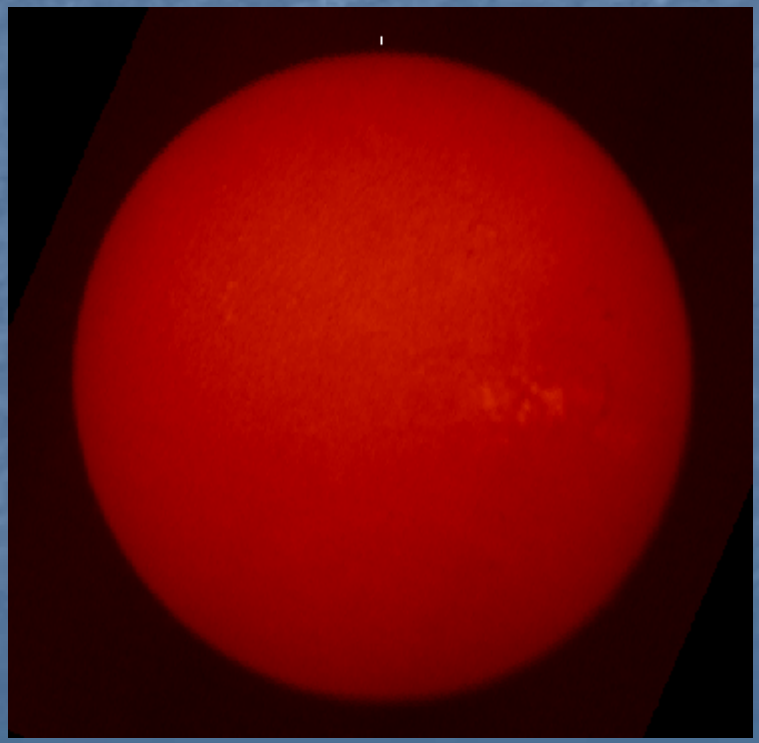
Use simulation for "Hard Problems".

Math is language which computers help us "translate".

Theoretical Astrophysics: Easy vs Hard

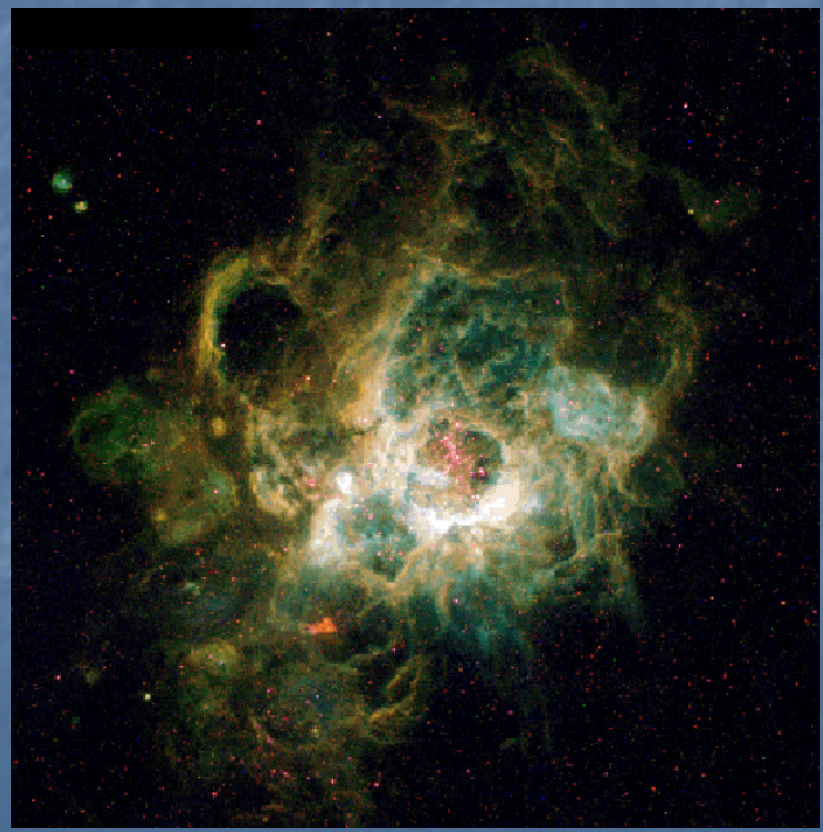
- **What's Easy? Spheres.**

Star

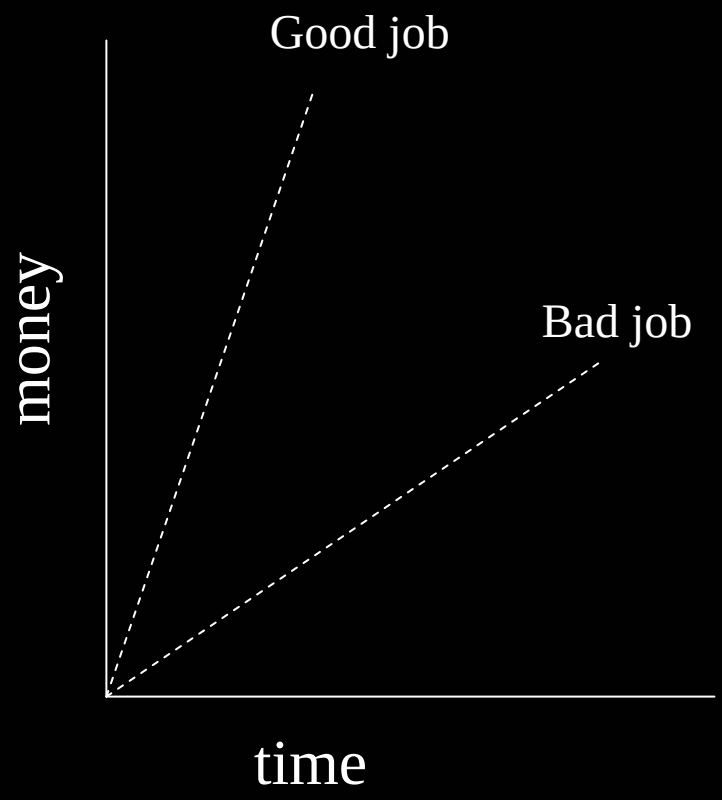


- **What's Hard? The Rest.**

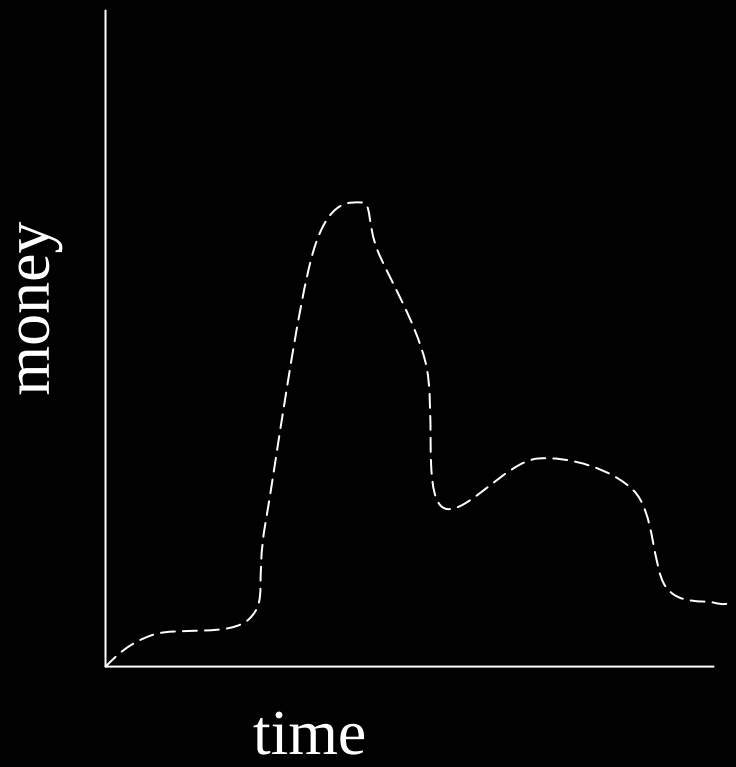
Star Formation



Math: Easy vs Hard



Money = Payrate * Time



Money = investments + stock market + Payrate * Time

Fluid Dynamics: The Equations of Doom

$$\frac{\partial \rho}{\partial t} + \vec{\nabla} \cdot \rho \vec{u} = 0$$

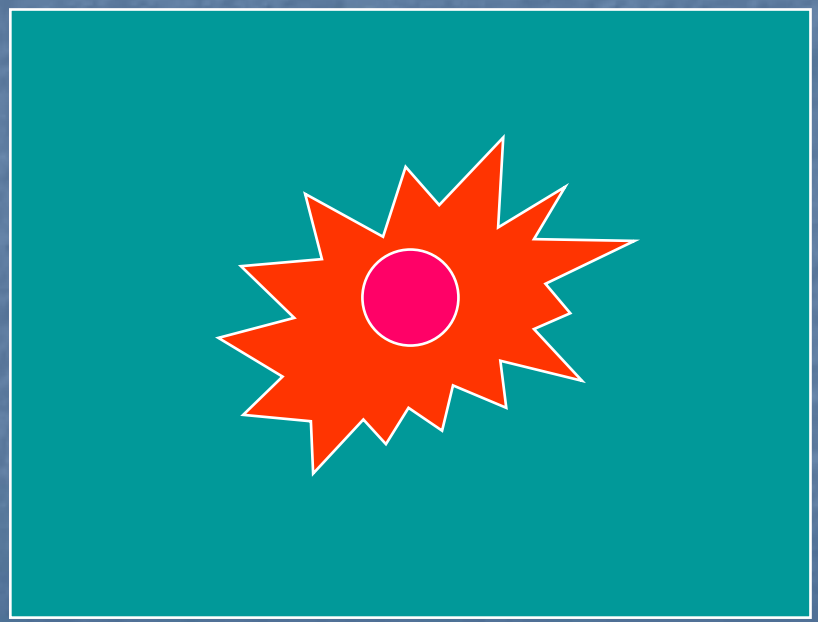
$$\frac{\partial \rho \vec{u}}{\partial t} + \vec{\nabla} \cdot \rho \vec{u} \vec{u} = -\vec{\nabla} P$$

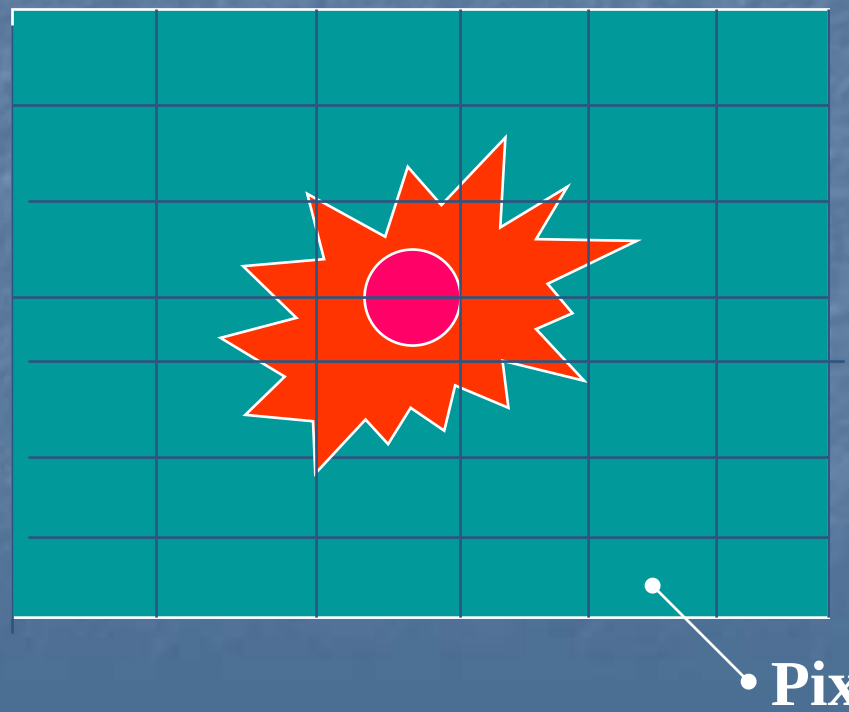
$$\frac{\partial E}{\partial t} + \vec{\nabla} \cdot \vec{u}(E + \frac{\gamma}{\gamma - 1} P) = -\rho^2 \Lambda(T)$$

Mass: ρ = mass density
Momentum: u = velocity
Energy: P = Pressure

How Computers Solve Problems: Space

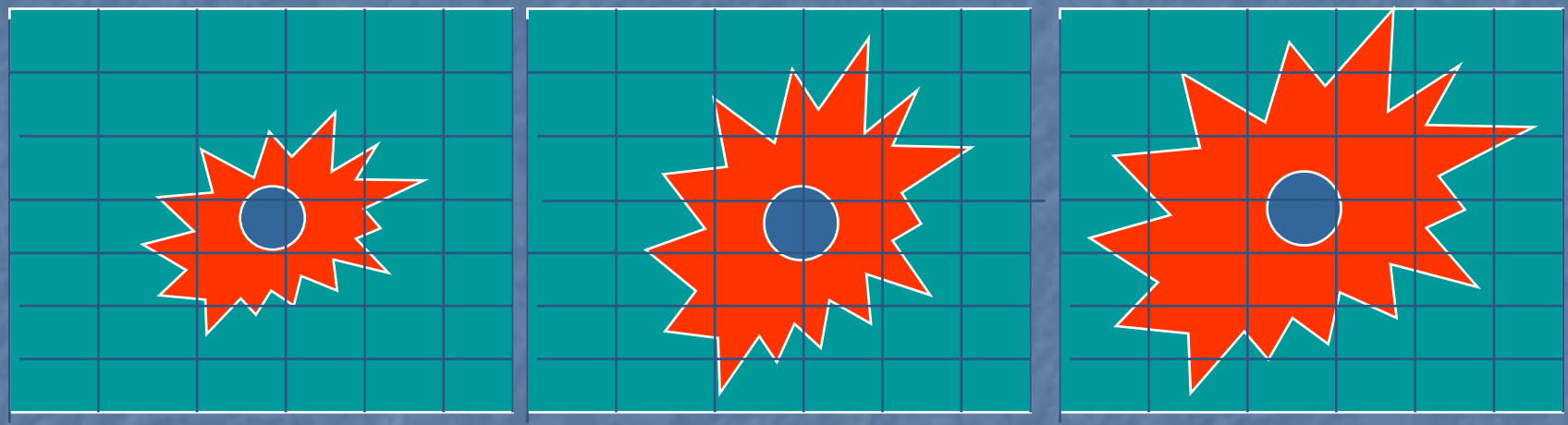
- Take a continuous world and make it discrete.
- Break space into computational cells.





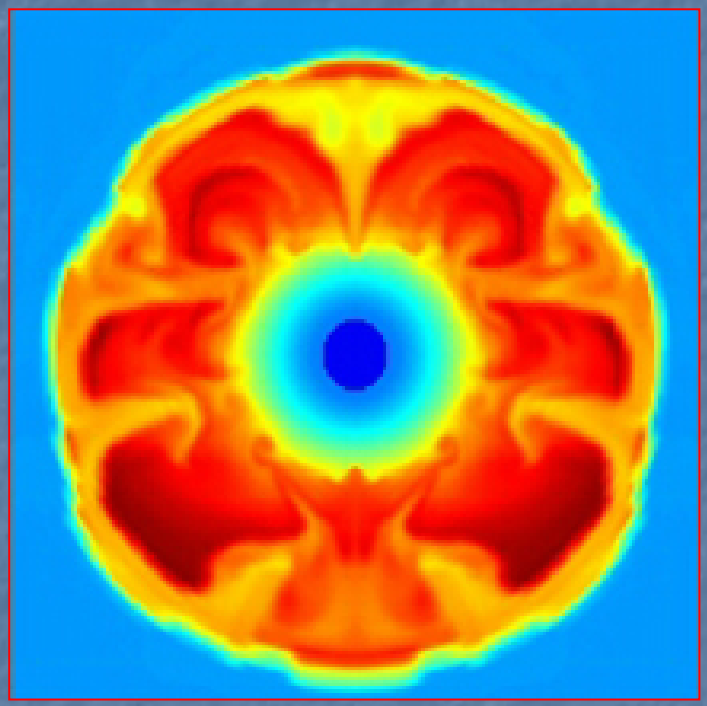
How Computers Solve Problems: Time

- Advance the solutions in lots and lots of tiny steps.

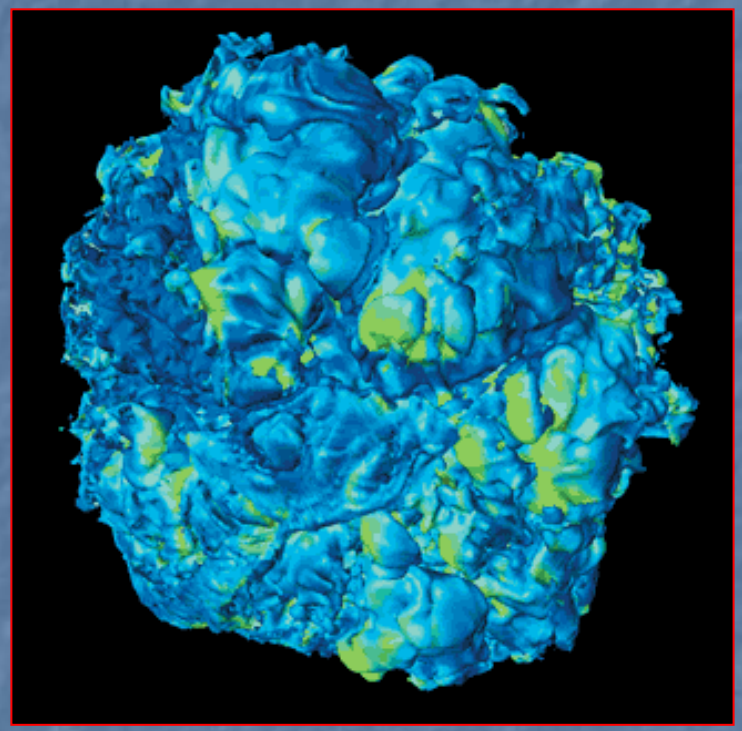


1 2 3

2 Supernova Simulations



Two-dimensional simulation of a supernova explosion, A. Mezzacappa, UT/ORNL.



3D supernova simulation *A. Mezzacappa R. Toedte, Oak Ridge National Laboratory, and John Blondin, North Carolina State University*

Who Needs Simulations?

- Simulation is key for many/most areas of science and engineering (NASA pushes envelope!)
  - Climate/Weather.
  - Aerodynamics.
  - Automotive engine design.
  - Financial Forecasting !
  - Microchip design/fabrication.
  - Computer Networks !

Who Simulates?

- Simulation requires a variety of kinds of skills
  - Mathematics.
  - Engineering.
  - Computer Programming.
  - Network management.
  - Database management.
  - Analysis.

Building Sci-Games

- 2001 Adam Frank, Prof of Computational Astrophysics at University of Rochester forms Truth-N-Beauty Software via technology transfer from NASA and NSF Grants.
- Mission: creates simulation based learning tools.

Building Sci-Games

- Science “games” developed with NASA appear on DISCOVER, ASTRONOMY and SCIENTIFIC AMERICAN websites.
- Education - another example of using simulation.

The Science of SatNetBuilder

Grant funding from NASA CICT

- Earth orbiting satellites and deep space probes must communicate with ground stations, and perhaps, each other.
- Communication may be instructions, images, instrument readings.

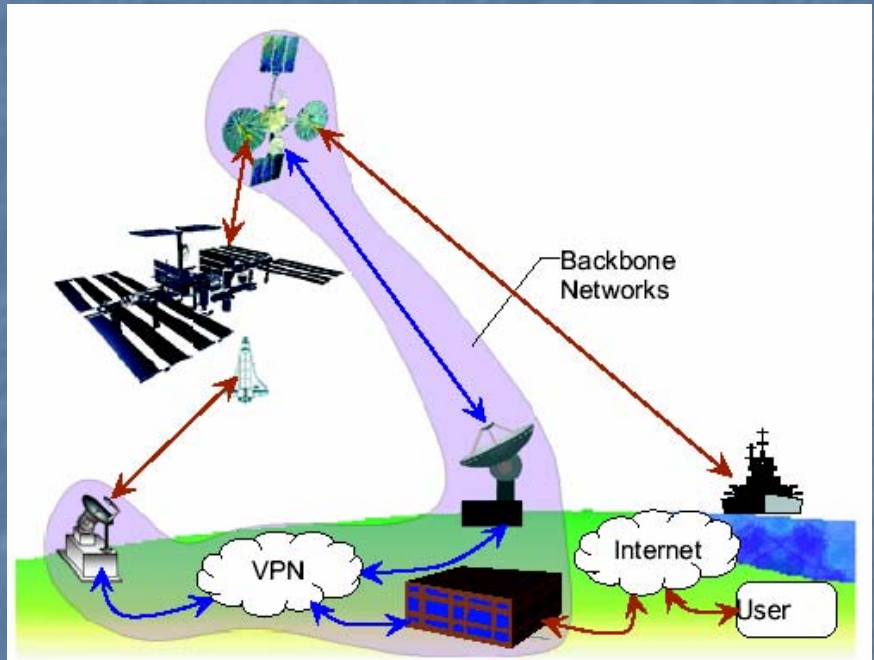


Figure 2, Backbone Network Elements

The Science of SatNetBuilder

- Key Point - The rate at which information can be passed depends on many factors such as
  - The transmitting power of antennas.
  - The sensitivity of receivers.
  - The distance between receiver and sender.
  - The “visibility” of receiver and sender.

SatNetBuilder Science

- More complex demands on space missions mean more complex demand for space communications networks.
  - Example: Mars probe and Mars orbiter must talk to each other and to the Earth while Earth and Mars orbit Sun.
  - Does it make sense to also place relay-station satellites in orbit between the two planets?

SatNetBuilder Science

- NASA Space Communications project explores how to build an “internet in space”
- Reliable cheap network of satellites which any space mission could use as a network “backbone”.
- Very cool idea!

Building the Internet in Space
Mars Mission Step 1

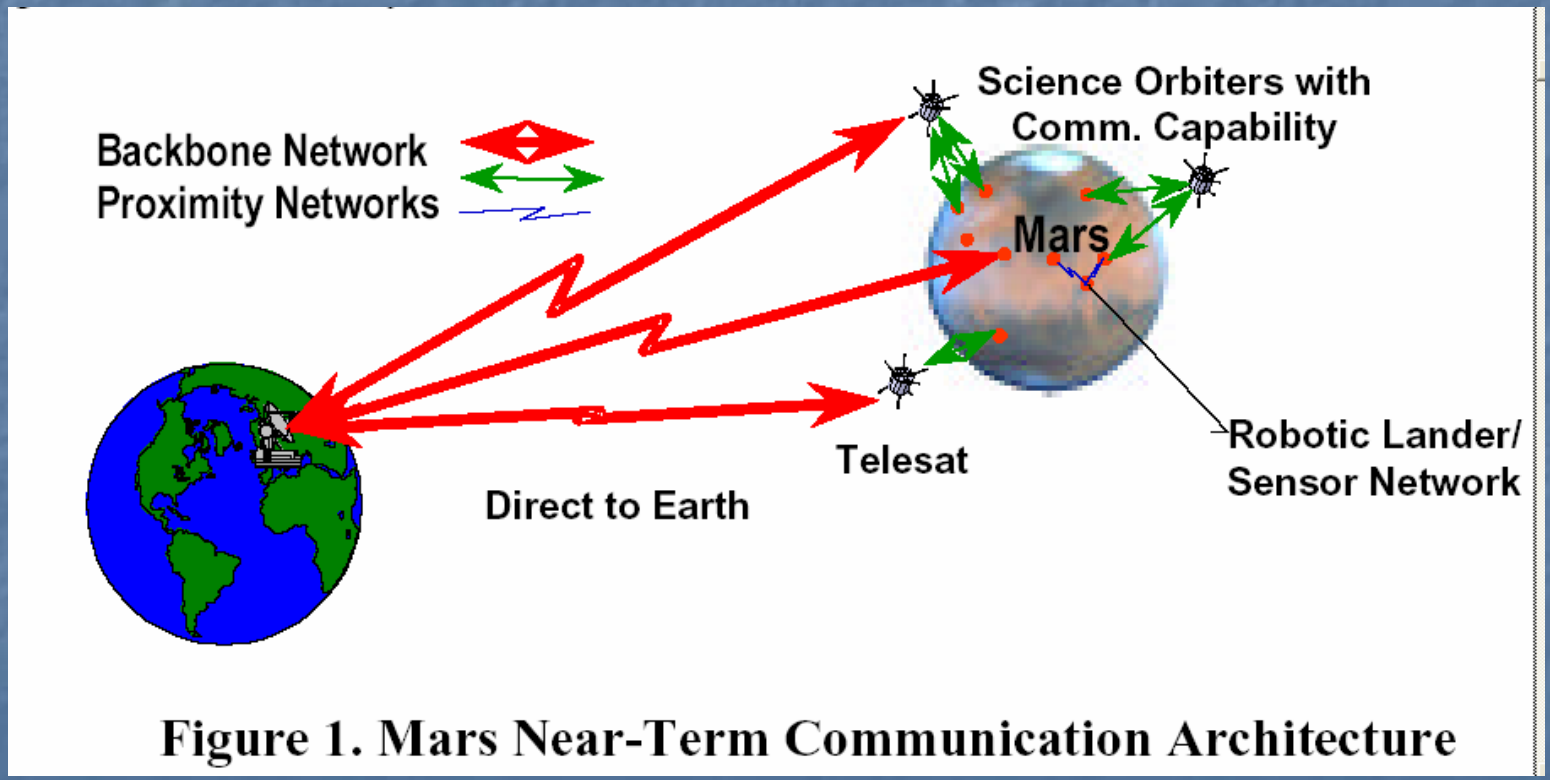


Figure 1. Mars Near-Term Communication Architecture

Building the Internet in Space
Mars Mission Step 2

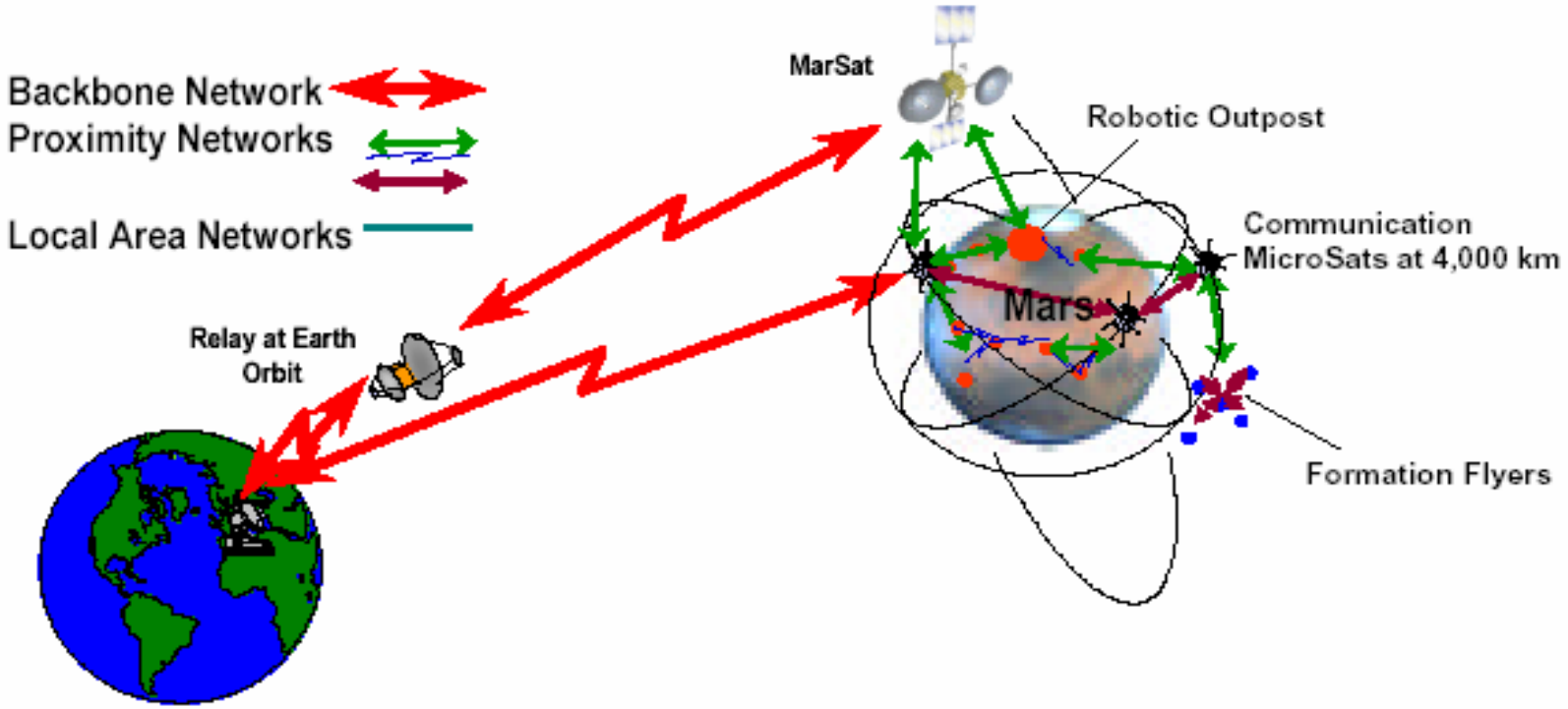


Figure 2. Mars Mid-Term Communication Architecture

Building the Internet in Space
Mars Mission Step 3

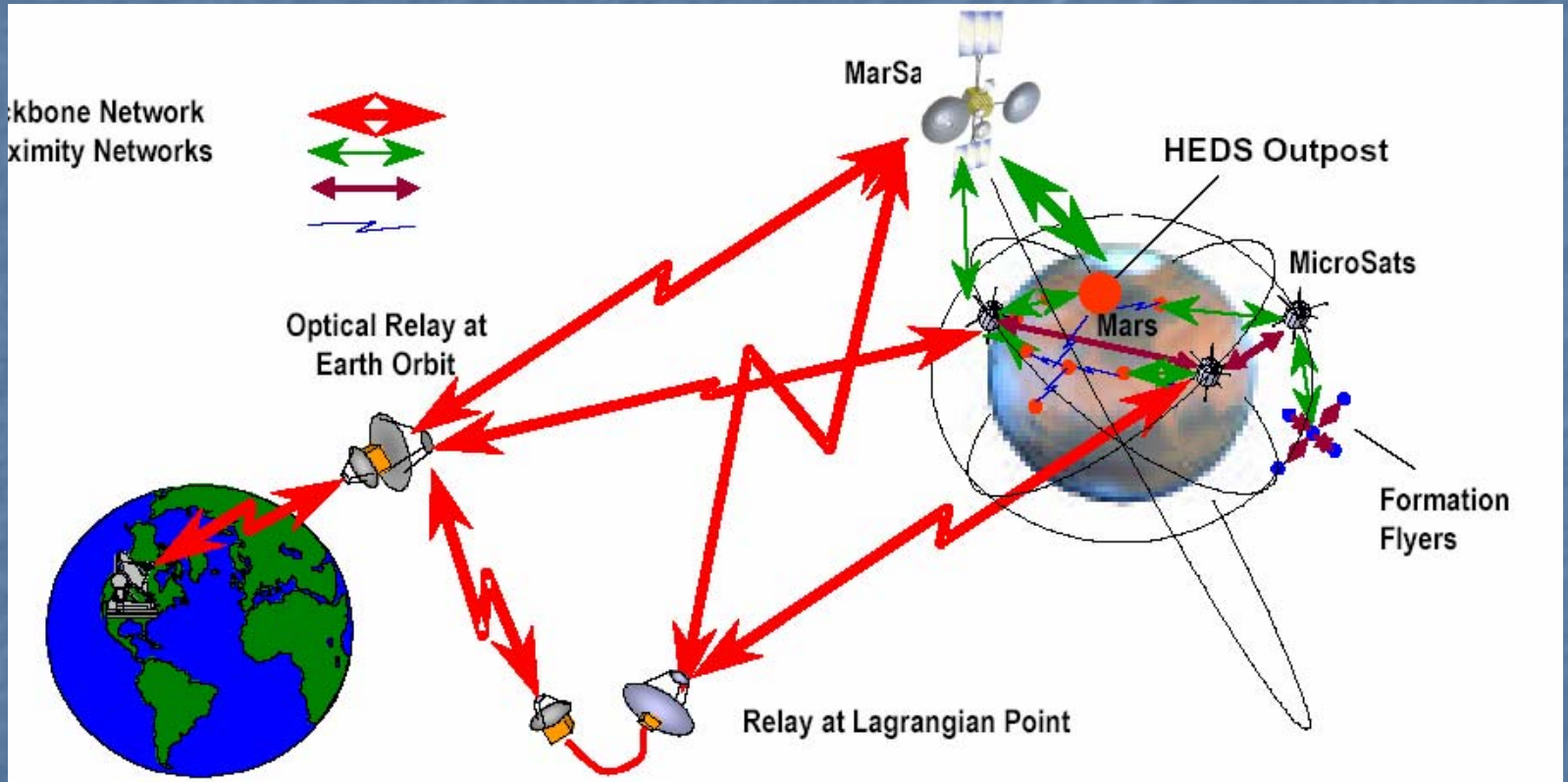


Figure 3. Mars Far-Term Communication Architecture

SatNetBuilder

- Concept: Allow students to explore creation of satellite communications network.

To Build SatNetBuilder we had to:

- know orbital physics.
- Know equations determining “Baud Rate”, rate information transfer from transmitter (satellite) to receiver (ground station)

SatNetBuilder v0

- One satellite, many ground stations.
- You have a specific mission budget.
- Everything costs.
- Must get best Baud Rate and stay within budget.
- Now in final testing phase, due out in near future.

Step 1: Build Satellite

Step 2: Place Ground Stations

Step 3: View Transmission

Conclusion

- Simulation is key in all aspects of science, engineering and business.
- Lots of job opportunities in simulation (NASA needs good people!)
- Simulation requires understanding problem and ability to analyze unexpected results.
- Simulation is a great way to learn.
- Internet in space is great frontier!